SYSTEMIC

Brochure

Recovery of nutrients and resources from digestate

2021

User preferences for digestate derived products

Extract from D 3.4 Market research in Europe -2021

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Introduction

There are many stakeholders possible that could adopt the use of fertilisers with recovered nutrients. The SYSTEMIC project suggests that to a certain extent these recycled nutrient products could replace mineral fertilisers. To get a better idea in which market segment this replacement potential lies, the end user preferences and/or requirements of certain key stakeholders are analysed in this chapter.
(Jensen et al. 2016) described the stakeholder mapping in Figure 3-1.

In this part of the report, the preferences of the primary stakeholders: crop-farmers, horticultural producers (vegetables, ornamentals) and private garden owners are looked at. This because they have relatively high power, as they are the direct users of alternative sources of nutrients (mineral fertilisers) and have the power to decline the recycled nutrient fertilisers, based on their preferences and the fulfilment of their requirements by the recycled nutrient fertilisers.

The preferences of agricultural consultants as secondary stakeholders are also taken into account because they cannot directly advise crop farmers and therefore influence their interests. They however will base their preferences more on an objective point of view, combining their knowledge on crop demand, environmental impact and safety, and general drivers from the whole stakeholder group of crop farmers.

The requirements of mineral fertiliser industry as secondary stakeholder are also included in this analysis. This is because recycled nutrient fertilisers could also function as secondary resources, hereby directly replacing fossil based nutrients (N, P,K) in the production of (organo-)mineral fertilisers.
The interest in recycled nutrient fertilisers of all stakeholder groups mentioned is generally low. By analysing their preferences and requirements, recycled nutrient fertilisers could be better finetuned to meet the demand of the market and be better accepted.

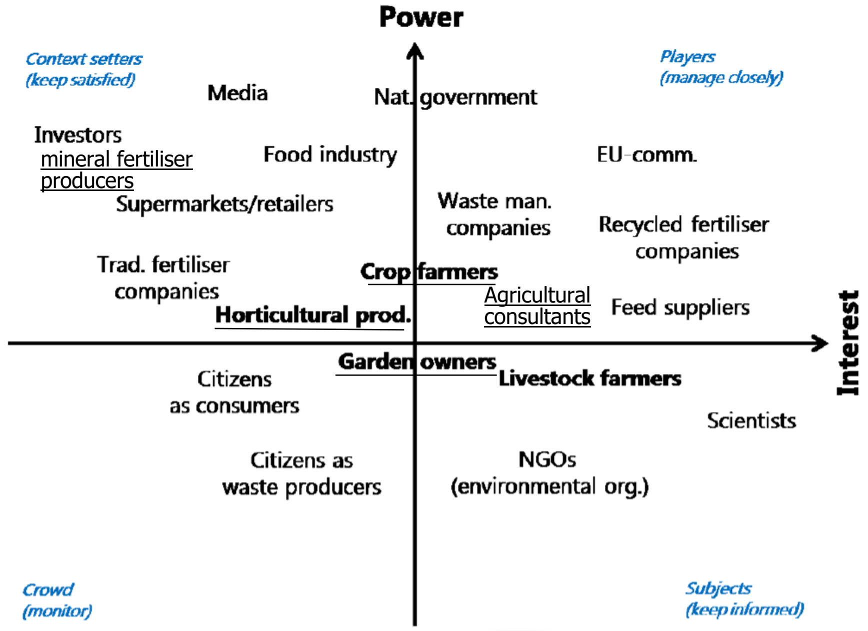

Figure 0-1 Stakeholder interest-power matrix, with primary stakeholders indicated in ***bold****. The stakeholders' whose preferences and/or requirements are analysed in this chapter are underlined. Italicised blue text indicates the four types of stakeholders (according to Ackermann and Eden, 2011, depending on their power and interest and in brackets actions to manage such stakeholders. Adapted from: (Jensen et al. 2016)*

Product quality and composition

Nutrient content and ratio

Crop farmers and horticultural producers

Consistency in nutrient content is regarded by producers as necessary to create a standardized product, which builds trust between producer and customer (Dahlin, Herbes, and Nelles 2015).
Unfortunately, the N, P, K concentration of products from digestate can vary largely. This is one of the primary barriers for farmers to use organic fertilisers (Case et al. 2017; Tur-Cardona et al. 2015). Therefore, it is crucial, as a producer of recovered nutrient products, to be transparent about the composition of the product, especially if it doesn't meet fully meet with the criteria of the end users.

When farmers and advisors were asked about the parameters and properties of (recovered) fertilisers, nutrient content, quality and composition were the most frequently occurring responses.
Both farmer and advisor prioritized knowing the nutrient content of the fertilisers over how well the fertilisers work with the plants and in the soil (Dahlin et al. 2016; Power et al. 2019; Power and Egan 2020; Tur-cardona 2015).

There was a difference between the preferences of users that were already familiar with the use of recycled nutrient fertilisers and those that weren't. When having to rank predetermined preferences, "a nutrient ratio that fits with crop nutrient demand" was the number one preference of users of recycled nutrient fertilisers, in particular in Ireland, while non-users only ranked this after price, ease of application and certification (Power and Egan 2020).

Garden owners

For many private customers, it is difficult to assess the quality of a new product. Many gardens are over-fertilized suggesting that gardeners don't pay much attention to the nutrient crop demand and if the nutrient composition of the fertiliser matches with this. Results from a choice experiment with German gardeners, indicated that the majority of respondents displayed a "more-is-better" preference for high NPK values (Dahlin et al.

2016). When it comes to soil amendments, many gardeners also don't know the composition (Dahlin, Nelles, and Herbes 2017).

However, it is important that details about nutrient composition and information about product appear on the packaging to guide customers towards environmentally safe use and making informed purchasing decisions (Dahlin et al. 2015).

Mineral fertiliser industry

Mineral fertiliser industries/producers need to comply with strict regulation, guaranteeing a product with constant composition, high purity and stability over time. Table 0-1 gives a rough indication of the quality of recovered nutrient products (as secondary raw material, expected by mineral fertiliser producers. They expect the secondary raw materials to have a similar quality as the primary resources they are currently using, because of the quality standards their customers are currently expecting from the end product.

A constant quality of the secondary raw material is also necessary for a good integration in the production process. Heterogeneous products with variable composition would repeatedly require a constant finetuning of the following process steps. Often the technical boundaries of the systems producing these secondary raw materials from digestate, limit the production of this kind of homogeneous and pure products. If this is the case and constant quality cannot be delivered, the amount of heterogenicity per product and contaminants should be mapped and the error margin should be determined, informing the mineral fertiliser producer of the quality and potential risks for the process.

A better reproducibility of the products could be achieved by finetuning the pre-treatment steps or by adjusting the nutrient content by making blends with products with a more stable concentration like ammonium sulphate, ammonium nitrate, ammonium water or solid fraction. Blending products also fits better to the differentiated demand of the consumers by making high variety of products.

Table 0-1. Indicative concentrations of nutrients in secondary raw materials requested by mineral fertiliser producers. Ntotal= total nitrogen, NH4-N= ammoniacal nitrogen, P2O5=ortho-phosphate, K2O=potassium oxide, DM=dry matter

	Solid secondary raw material [1]	Liquid secondary raw material [1]	Ca-phosphate [2]	Struvite[2]	P-salts [3]
Form				>2 mm	Powder or granulates
% solids	-	<3	As high as possible		As high as possible
% Ntotal	>10	>5			
% NH_4-N			Max 30 (3g/kg)		
% P_2O_5	>10	>5	>6 <10, but only if dry product		>9,2
% K_2O	>10	>5			
% DM	>85	-			

Desirable Valuable Mandatory

1 (Brañas and Moran 2016)

2 (personal communication 2018)

3 (Postma et al., 2011)

Organic matter

When agricultural land is cultivated intensively organic carbon can be depleted from the soil, because of the removal of organic carbon that has been incorporated in harvested crops.

Manure and other bio-based products containing organic carbon can help replenish this organic matter in the soil, contributing to and improved soil structure, biodiversity and less soil erosion.

In contrast to mineral fertilisers, most recycled nutrient fertilisers from digestate contain organic matter, from which a (large) part does not mineralise during the first year of application (Vannecke, Gorissen, and Vanrespaille 2018; VLACO 2016).

Crop farmers and horticultural producers

Farmers clearly indicated in both studies (Case et al. 2017; Tur-Cardona et al. 2018) that one of the major advantages of recycled nutrient fertilisers products is the content of organic matter/carbon.

In the survey of (Power and Egan 2020) users of recycled nutrient fertilisers ranked high organic matter as the second most important quality, especially in the Netherlands.

Mineral fertiliser industry

In contrast with farmers, mineral fertiliser producers require low levels of organic matter (e.g. carbon) in a secondary raw material especially in combination with nitrate (nitrogen), because carbon can be a catalyst for explosions in N-fertiliser production processes and the combination of high levels of nitrate and organic matter can cause self-ignition. Additionally, the presence of organic matter reduces the efficiency of the polymer added to extract impurities (personal communication, 2017).

Pathogens and heavy metals

Crop farmers and horticultural producers

Elimination of germs and bacteria can be achieved through heat treatment, also called hygienisation. This is included in Regulation (EC) 1069/2009 laying down health rules as regards animal by-products and derived products not intended for human consumption, after several severe crises in the food-and feed sector. In the study of (Tur-Cardona et al. 2018), one group of respondents (75% of the respondents) showed positive preferences for hygienisation of the product.

This can indicate that some farmers still believe that products (from manure or organic waste) contain large amounts of animal pathogens or heavy metals. Nonetheless, this is probably only a perception, since analyses on mineral concentrates after membrane filtration of manure have shown that these were present in traces or absent altogether (Ehlert, Hoeksma, and Velthof 2009).

Analyses performed in the framework of the SAFEMANURE study, showed that the 8 mineral concentrate samples complied with the proposed levels for Cu and Zn, while the limit for Hg (1 mg kg^{-1}) was exceeded by 70% of the mineral concentrate samples. It is still internally discussed if the analytical method used, was reliable and reproducible(Huygens et al. 2020).

The measured concentrations for Hg were similar to those in raw manure (mg Hg/kg dry matter). Thus, it could be assumed that mercury is preferentially distributed towards the liquid fraction during manure or digestate solid-liquid separation, although advanced solids removal and/or reverse osmosis processes may reduce Hg accumulation in mineral concentrates (Huygens et al. 2020)

Tests on struvite recovery from human urine showed that struvite without organic micro-pollutants and limited amount of metals could be recovered (Nuresys; Ceulemans and Schiettecatte 2013).

Garden owners

The presence of heavy metals and pathogens are obviously perceived by gardeners as negative attributes in a fertiliser of soil improver. Mostly not aware of the safety limits for heavy metals and pathogens, private consumers are known to apply several risk reducing strategies, like using price as a quality indicator and so buying the most expensive product, or relying on the brand name to signal a trustworthy supplier (Dahlin et al. 2017).

Labelling a product as “organic” communicates value to environmentally aware gardeners, which in many cases have the misconception that that ‘organic’ meant free from heavy metals, pesticide residues and chemicals (Dahlin et al. 2017).

Mineral fertiliser industry

Mineral fertiliser producers expect low levels of heavy metals in secondary raw materials. These specifically concern iron (Fe), metals that can volatize during the production process (Zn, Pb, Cd, Sn) and chloride, which can cause corrosion. Cu and chlorides can – similar to carbon- be catalysts for explosions in N-fertiliser production processes.

Unfortunately, when extracting phosphorus from secondary raw materials, obtaining a pure end product can be difficult, because often a mixture of P-salts (and often also a part organic material) are retrieved from digestate, manure or WWT sludge which first have to be acidulated or transformed into phosphoric acid which in turn can be further transformed.

This process dissolves e.g. Mg from struvite, which will be transformed to Mg-sulphate in the process. This is an unwanted component which needs to be removed and therefore does not make struvite salts an interesting secondary P resource for chemical industry. Acidulation also dissolves the heavy metals present in the P-salts. A large amount of heavy metals therefore represents a high extraction cost (personal communication VCM, 2015).

Calcium phosphate ($Ca_3(PO_4)_2$) could potentially be of interest, but problems remain with granulation and there are issues with the extraction and production of clear crystals (Lebuf and Elsacker 2015). Calcium phosphate is highly preferred as raw material by the P fertilising industry. Therefore, it is important that it contains no iron, because iron phosphate is a not a soluble mineral phosphate and it could alter the colour of the gypsum by-product to brown. Absence (plasterboards) In the last case a of $CaCO_3$ is also required, since this would produce foam during the process.

Anyhow, some fertiliser companies are open to analyse a sample and feedback on how the concentration should be adjusted and which impurities should be resolved (personal communication VCM, 2018).
Some fertiliser companies are even more flexible and claim to be able to use all kinds of phosphorus streams, preferably with high P content. This is because the impurities of the relatively small recovered phosphorus stream will be diluted during the process (Notenboom, Helmyr, and Van der Zandt 2017).

In the industrial practice, ammonium sulphate is a common by-product and will most likely have some impurities from different sources. The same counts for recovered ammonium sulphate from digestate.
For use in agriculture these impurities are regarded negligible, but to be able to create a value for this product in industry, and to for example crystallise it, a high concentration (>20%) and high purity is required (GEA 2010).

Table 0-2 gives an indication of quality requirements related to contaminants for recovered nutrient products set up by mineral fertiliser producers.

Table 0-2. Indicative criteria for contaminants provided by mineral fertiliser producers. DM=dry matter, TOC= total organic carbon, C = carbon, MgO=magnesium oxide, CaO=calcium oxide, SO_3=sulphur tri-oxide

	Recovered nutrient products [1]	P products for Non-food uses [2]	P product For feed [3]	P product food and beverages [3]	Solid secondary raw material [4]	Liquid secondary raw material [4]	Ca-Phosphate [5]
DM%					>85	-	
TOC%					<2	<2	
C%	Max 0,1% when 100% recovered products are used						<5
MgO%		<5ppm			>2	>1	
CaO %		<5ppm			>2	>1	
SO_3 %				<3400 SO4	>2	>1	
Fe %		<5ppm			>1	>1	
Mn %					>2	>1	
Zn (mg/kg)					<400	<400	Not present
Cu (mg/kg)					<100	<100	Not present
B (mg/kg)					>1000	>1000	
Mo (mg/kg)					>1000	>1000	
Cd (mg/kg)	Max			<3	<10	<10	Not present
As (mg/kg)	10%(w/w)		<40 ppm <8000ppm	<3	<40	<40	Not present
Pb (mg/kg)				<3	<150	<150	Not present
Al (mg/kg)					<1500	<1500	Not present
Cr (mg/kg)					<100	<100	Not present
Cr V (mg/kg)					0	0	Not present
Hg (mg/kg)				<3	<2	<2	Not present
Cl g/kg				<600			0,15
Volatile acids				<30			
SiO_2							As low as possible

Desirable valuable mandatory

1 (personal communication, 2014)
2 (Schipper, W., 2013. Personal communication)
3 (Dikov et al. 2014)
4 (Brañas and Moran 2016)

5 (Personal communication 2018)

Ease of use

Among respondents of the survey performed by (Power and Egan 2020), farmers ranked the ease of use as the 3rd most important parameter when selecting fertilisers.

Farmers not familiar with recycled nutrient fertilisers and advisors ranked it 2nd most important after price, particularly in Ireland.

In particular, farmers specified ease of use as: the ease of application/ spreading, followed by the fertiliser texture, ease of storage, fertiliser formulation, fertiliser size and dust formation.

Crop farmers and horticultural producers

Today, farmers depend on the availability of local agricultural contractors with equipment that can spread the products competitively. Respondents of a survey of European farmers mostly prefer farmers will prefer to use a dry, granulated or pelletised, concentrated fertiliser over liquid products, because of the ease of application and logistics (Jacobsen, Bonnichsen, and Tur-cardona 2017; Power and Egan 2020; Tur-Cardona et al. 2015). In contrast with the airiness of dried digestate, granulated products have bulk weights of over 600 kg per cubic meter, and interviewees indicated 300 kg per cubic meter as the minimum bulk weight needed to make long distance transportation cost effective (Dahlin et al. 2015). Eastern farmers also expressed preferences for semi-solid fertiliser products like digestate (Tur-cardona 2015).

In general, when it comes to liquid fertilisers, farmers prefer volumes comparable to their mineral fertiliser (Tur-cardona 2015). However, the recycled nutrient fertilisers are frequently liquids with low concentrations of nutrients, meaning that a much larger volume is needed for the same amount of nutrients administered with a mineral fertiliser.

The related transportation costs of these high volumes also often hinder distribution over long distances and practical application (Huttunen, Manninen, and Leskinen 2014). For example, on heavy soils (like clay) it is not advisable to spread large weights and liquid products because this might contribute to soil compaction, soil structure and crop damage. On lighter soils (sand, loam,...) liquid products have more opportunities (Smit, Prins, and Hoop 2000).

On the other hand, the current agricultural machinery also has limits on the practical application of small volumes (e.g. <10 tonnes/ha). To do this, the injector would have to drive faster, which could cause e.g. wheat to be teared loose (de Hoop et al. 2011). However, some recycled nutrient fertiliser producers have designed adapted application machinery for these types of products (personal communication Groot Zevert Vergisting, 2020). In general, administration with a sod injector, towing machine, arable injection or a tanker with trailing hoses are perceived by farmers as convenient for low-emission administration of liquid products (de Hoop et al. 2011).

Garden owners

Similar to farmers, hobby gardeners may perceive powdery products as dusty and product difficult to apply in a controlled way, particularly as it is susceptible to drifting with the wind. These customers want a homogenous product that can easily be applied with their current gardening tools and the products do not stand out aesthetically. Again, this translates to a preference for granulate products in this stakeholder group (Dahlin et al. 2015).

When it comes to potting soils, only more engaged gardeners pay attention to observable differences between potting soils. Fine grained and clump-free soils were preferred and associated with the better and more expensive products. The cheaper products were perceived as more likely to contain inert foreign materials such as plastics and stones (Dahlin et al. 2017).

Mineral fertiliser industry

When used as secondary raw material there are limitations set to the water content in function of treatability. For this reason, preferably dry, inorganic streams are used (Ceulemans and Schiettecatte 2013; Lebuf and Elsacker 2015). Additionally, some mineral fertiliser producers do not have the equipment to pelletise and can therefore not process sandy or slurry-like products.
Others are willing to accept slurries but prefer dried products because of the cost for logistics and drying. Organic fertiliser companies producing pellets can only handle solid products in their process lines.

The amount of struvite that can be added to organic fertilisers to improve the P content is limited, since struvite is not “sticky” enough to press in large quantities and the N/Mg/P ratio is not in line with products expected by the costumers. Others claim that they can pelletise struvite, but only when it contains more organic matter (personal communication, 2018).

There is an interest in N-containing liquid products, but mostly only a limited amount (10%) can be mixed with other products. Therefore, the N products would need to have a sufficiently high concentration to have an added value as secondary raw material (personal communication, 2018).

Fertiliser companies also require a constant supply of large volumes of secondary raw materials to keep the process line running. This is estimated at minimum 10% of annual volume of the primary resource they process. To adjust the production process to the impurities of the batch, minimum amounts of 20.000 tonnes can be demanded (personal communication, 2014).

Some mineral fertiliser producers are willing to accept smaller amounts, if they are compensated by a sensible gate fee and research results on lab scale towards the technical possibilities. This to provide a guarantee against damage and contamination of their production process.
Table 0-3 gives an indication of required volumes of related nutrient products set by mineral fertiliser producers.

Table 0-3. Indicative values preferred volumes and transport costs.

	Solid secondary raw material [1]	**Liquid secondary raw material** [1]	**Ca-phosphate** [2]	**Struvite** [2]
Tonnes/year	>5000	>5000	200 (P_2O_5) 1000 (80%DM)	1000
Transport costs	<15€/tonne	<15€/tonne		

1 (Brañas and Moran 2016)

2 Personal communication, 2018

Price

Crop farmers and horticultural producers

Most studies that asses user preferences confirm that for conventional arable farmers product cost was the most important quality for recycled nutrient fertilisers (Case et al. 2017; Jensen et al. 2016; Power and Egan 2020).

The results of the survey of Power and Egan, 2020 showed this result when users familiar with recycled nutrient fertilisers responded to an open-ended question. However, price ranked 2nd most important by them after product quality in a ranking exercise. In comparison, for non-users, the price per unit of N or other nutrients in particular in Ireland was the most important quality in recycled nutrient fertilisers (Power and Egan 2020).

Horticultural producers operate in markets with much higher profit margins and hence have a larger willingness to pay for the right product (Jensen et al. 2016).

Tabel 0-1 Different references estimating a price for recovered nutrients

Reference	Product	Suggested price
(Notenboom et al. 2017)	Struvite from wastewater treatment in the Netherlands	65€/ton Excl. transport cost
(Ceulemans and Schiettecatte 2013)	Struvite from wastewater treatment in Belgium	50-90€/ton
(NuReSys, Waregem, BE, personal communication 2013)	Struvite from wastewater treatment in Belgium	45€/ton
(Bolzonella et al. 2017)	ammonium sulphate (6% N, 30% ammonium sulphate)	30 €/m³
(Dikov et al. 2014).	P-salt product that more or less meets with the quality requirements of the company	Same price as phosphate rock i.e. 176-327€/tonne P2O5)
(Bussink and van Dijk 2011a)	struvite	½ to 2/3 of price TSP
(VCM and Fraunhofer IGB 2015)	P-salt	50€/ton
Pilot Mineral concentrates NL 2009 2010	Mineral concentrates Price paid by farmers	 1,25€/ton 1,19€/ton
Personal communication SYSTEMIC plant, 2018	Ammonium sulphate solution	10-25€/ton

As a producer of recycled nutrient fertilisers, when making a well-considered price estimation, one also has must consider the cost for application technique and maximum amount that can be applied each time within a growing season. (Gl Velthof 2011) suggest minimally 10% lower than the price of mineral fertilisers and application cost. (Jacobsen et al. 2017) concludes that it is difficult to get farmers to pay more than 50% of the mineral price for a bio-based product (Table 0-4).

Table 0-4. Willingness-to-pay for recovered nutrient products based on literature and surveys.

Source	Product	Suggested price	Remark	Spreading cost
(Dodde 2012).	Mineral concentrate (7,12 kg N/ ton; 9,07 kg K2O/ ton)	2€/ton	Grass or corn	
(G. Velthof 2011)	N-rich products	Minimally 10% lower than price of CAN i.e. 210 €/ton		Application costs similar to those of mineral fertiliser application: estimated 2,5€ ton [2]
(Jacobsen et al. 2017)	Bio-based fertiliser	50% of price of mineral fertiliser	Class 2 farmers "old and not interested"	The cost of application of slurry is 1,34€/ ton and with 5 kg N per ton which is around 0,27€/ kg N. Application of mineral fertiliser is around 0,15€/kg N/ton.
	Bio-product 1: [4] Granulate, x7 volume of mineral fertiliser, 10% uncertainty in N content, with organic carbon	8% of price of mineral fertiliser Will not pay	Class 1 farmers "Young and interested" Class 2 farmers "old and not interested"	
	Bio-product 2: Granulate, x4 volume of mineral fertiliser, 5% uncertainty in N content, with organic carbon	34% of price of mineral fertiliser Will not pay	Class 1 farmers "Young and interested" Class 2 farmers "old and not interested"	

Source	Product	Suggested price	Remark
(Jacobsen et al. 2017)	Bio-product 3: Granulate, same volume as mineral fertiliser, no uncertainty in N content, with organic carbon and fast release of nutrients	51% of price of mineral fertiliser	Class 1 farmers "Young and interested"
		27% of price of mineral fertiliser without fast release of nutrients	Class 2 farmers "old and not interested"
		40% of price of mineral fertiliser with fast release of nutrients	
(Power et al. 2019)	Recycling-derived fertiliser	Free of charge	18%
		Same price of mineral fertiliser	17%
		Same price or 80% of price of mineral fertiliser	19%
		50-80% of price of mineral fertiliser	23%
		<50% of price of mineral fertiliser	14%
			Of 691 respondents
(Tur-Cardona et al. 2015)	Solid form	18% of price of mineral fertiliser	Flemish farmers (Belgium)
	Presence of organic carbon	28% of price of mineral fertiliser	
	Hygienisation	20% of price of mineral fertiliser	
	Fast release of nutrients	11% of price of mineral fertiliser	
(Tur-Cardona et al. 2018)	Solid fertiliser	44% of price of mineral fertiliser	Benelux
		39% of price of mineral fertiliser	Denmark
		31% of price of mineral fertiliser	Hungary and Croatia
	Organic carbon	52% of price of mineral fertiliser	Benelux
		17% of price of mineral fertiliser	Denmark
		35% of price of mineral fertiliser	France and Germany
	Hygienic	42% of price of mineral fertiliser	Benelux
		30% of price of mineral fertiliser	Denmark
		18% of price of mineral fertiliser	France and Germany
	Fast nutrient release	22% of price of mineral fertiliser	Benelux
	Pelletized	87% of N of mineral fertiliser price	
	All preferred characteristics	76% of N of mineral fertiliser price	
(Dahlin et al. 2015)	Bulk marketing :		Switzerland, Germany, France, Austria, Netherlands
	Raw (liquid) digestate	+5€/ton to -18€/ton	
	Pellets		
	Small scale marketing :	0 to 200€/ton	
	Powder product	9€/L	
	pellets	10€/ 4.5kg	

Source	Product	Suggested price	Remark
(VCM 2020)	Digestate (co-digestion)	-15€/ton	Flanders, Belgium
	Solid fraction digestate	-9€/ton	
	Liquid fraction digestate	-8€/ton	
	Dried digestate	-7€/ton	

Garden owners

In general, both for soils and fertilisers price is an important factor influencing the purchasing decision for fertilises (Dahlin et al. 2016). For some, low price is the decisive factor, and they only buy the cheapest product.
On the other hand, some consumers perceive price as a proxy for value and quality. Also, products labelled “organic” or “peat-free” and typically are among the more expensive soil amendment offerings (Dahlin et al. 2017).
In the potting soil market, where the profit margins are typically modest, this could be used to advantage (Dahlin et al. 2019).

Home garden products are mostly specialized fertilisers and can therefore be sold at much higher prices compared to fertilisers used in agriculture. However, this does not necessarily mean higher profit margins. These products incur additional manufacturing, packaging and marketing costs and, in addition, up to 60% of the remaining margin may be taken by the retailer (Dahlin et al. 2015; Dikov et al. 2014).

The consumer group of the serious hobby gardeners are prepared to pay a higher price for products of premium brands (e.g. that are perceived to be of premium quality) (Dahlin et al. 2017). When purchasing smaller quantities, the importance of the price per unit decreases. However, when larger quantities are required, the price per unit becomes increasingly more important.

For potting soil, since it is a product used in bulk quantities, customers sensitive to high prices place an even greater importance on price than they would for products like fertilisers that are purchased less frequently and in much smaller quantities (Dahlin et al. 2019).

SYSTEMIC
Circular solutions for biowaste

Mineral fertiliser industry

Mineral fertiliser producers usually are only willing to pay a price for recovered nutrients that is lower than what they currently pay for their primary nutrient resource. They find this necessary to balance the investment costs needed to adjustments their production process to the secondary raw material of inferior quality (personal communication, 2018).

Table 0-5 gives an overview of indicative prices for recovered nutrient products. The price

Reference	Product	Suggested price
(Notenboom et al. 2017)	Struvite from wastewater treatment in the Netherlands	65€/ton Excl. transport cost
(Ceulemans and Schiettecatte 2013)	Struvite from wastewater treatment in Belgium	50-90€/ton
(NuReSys, Waregem, BE, personal communication 2013)	Struvite from wastewater treatment in Belgium	45€/ton
(Bolzonella et al. 2017)	ammonium sulphate (6% N, 30% ammonium sulphate)	30 €/m^3
(Dikov et al. 2014).	P-salt product that more or less meets with the quality requirements of the company	Same price as phosphate rock i.e. 176-327€/tonne P2O5)
(Bussink and van Dijk 2011)	struvite	½ to 2/3 of price TSP
(VCM and Fraunhofer IGB 2015)	P-salt	50€/ton
Pilot Mineral concentrates NL 2009 2010	Mineral concentrates Price payed by farmers	 1,25€/ton 1,19€/ton
Personal communication SYSTEMIC plant, 2018	Ammonium sulphate solution	10-25€/ton

will be strongly influenced by the product quality and contaminants, transport cost, volumes, etc.

Reference	Product	Suggested price
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Personal communication SYSTEMIC plant, 2018	Ammonium sulphate solution	10-25€/ton

Table 0-5. Indicative values mineral fertilising companies are willing to pay for recovered nutrient products.

Conclusion

To get recovered products to enter the fertiliser market and compete on the same level as mineral fertilisers, they will first have to get acknowledged to be **applied as a mineral fertiliser**. The use of processed manure/digestate products under the same conditions as mineral fertilisers in nitrate vulnerable zones could be a major contributor for the feasibility of business cases of NRR in Europe. The creation of a market for the end-products of NRR techniques has a great impact on the financial viability of these investments.

On national level it is possible to ask for a derogation (See D 3.4 Market research in Europe ANNEX II.5 as example). In the framework of a project, an individual exemption from the application limit can be obtained by the regional or national ministry, limited in time and space, product, user.

This is also possible to file a group exemption on a larger scale, but still limited in time. This is not per se in the framework of a project (See D 3.4 Market research in Europe, Chapter 3.1.4 Pilots in the Netherlands).

A group of producers, each producing different products can contribute to a file to build their case for the European Commission. This should contain the description of the process, product characteristics, area on which the products would be applied, projects that could include and finance field trials.

A research centre should be involved to assure report on the field trials and independent organisation should be appointed to assess and monitor the product quality and monitor the number of products that is are applied. This is a time-consuming process for which biogas plants need the support of national sector organisations and research institutions.

The implementation of the RENURE criteria (See D 3.4 Market research in Europe, Chapter 3.1.5 SAFEMANURE) in European and Member State legislation, would harmonize the individual derogations and pilot-status.

It can be concluded that many regulations on European level have in recent years been creating openings for the use and trade of these new recycled nutrient fertilisers (e.g. FPR, SAFEMANURE study) and the Green Deal Farm to Fork strategy and the Circular Economy Action plan will further enforce this. It can therefore be assumed that legislation is not hinder the use of recovered nutrient fertilisers but rather the market conditions.

Livestock and horticulture farmers are the stakeholder groups that would most likely prefer characteristics of recycled nutrient fertilisers. Especially, when they have not experienced deficiencies in fertilisation with manure or are already familiar with the use of these products (Tur-Cardona et al. 2018).

Yet, an increasing amount of farmers start to see the value of organic matter, especially in Netherlands, for their contribution to soil quality, which yields a certain soil amelioration value (Jensen et al. 2016; Power and Egan 2020). Compared to mineral fertilisers, the organic matter content is generally higher is digestate derived fertilisers (except in scrubber salt solutions and liquid concentrates).

Nonetheless, product quality (consistent nutrient content) and price are the main factors influencing the farmers decision. The results from the study of (Power and Egan 2020) add that ease of use is also an important characteristic.

The open-ended question on price indicated that farmers would be willing to use recycled nutrient fertilisers as alternative fertiliser if they would be subsidized, available free of charge or at a price that is sufficiently low to compete with traditional mineral fertilisers (Power and Egan 2020).

The lower cost would be necessary to compensate the higher logistics cost (transport and application), less predictable nutrient content and availability, physical parameters (compatibility with handling and spreading equipment) and potential nuisance (odour, dust) for neighbours (Jensen et al. 2016; Power and Egan 2020).

Price is even more important if farmers are not familiar yet with the recycled nutrient fertilisers (Power and Egan 2020). This mainly has to do with the fact that they have lower trust in these new, unknown fertilisers and don't see their intrinsic (nutrient) value (yet). (Tur-Cardona et al. 2018) states some reasons for this:

Firstly, farmers typically stick to their habits and for fertilisation they have been using mainly manure and chemical fertilisers, which they therefore consider as the most reliable source of nutrients. Consequently, they tend to be suspicious of any new and untried products. This is more pronounced in the stakeholder group of older farmers (+65 years), who would only use recycled nutrient fertilisers if they would be free of charge or subsidised (Power and Egan 2020).

Secondly, the variability of the characteristics, origins and nutrient concentrations of the recycled nutrient fertilisers complicates the marketing of standardised products.

Thirdly, because these products are unfamiliar, farmers don't yet trust nutrient uptake efficiency by different crops. Demonstration projects could help overcome this issue, however good yield results might also depend on proper application and experience with recycled nutrient fertilisers.

Lastly, most recycled nutrient fertilisers are processed in regions with nutrient surpluses. While local farmers could aware of the benefits of recycled nutrient fertilisers (e.g. their organic matter content and nutrient value), nutrient surplus areas have a lack of available local agricultural land to apply the recycled nutrient fertilisers (and their nutrients). This gives local farmers strong bargaining power regarding price. In contrast, farmers further away, which could use the nutrients in recycled nutrient fertilisers, might have a lower awareness of these products and therefore are more difficult to convince. Additionally, transportation costs might become important.

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